B&P File No. 11229-6

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Title: Shear Wall Panel
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This is a continuation-in-part of PCT Application No. PCT/CA00/01221 filed by Thomas Leung on October 13, 2000; a continuation-in-part of US Patent Application No. 09/419,934 file by Thomas Leung on October 18, 1999; and, a non-provisional of US provisional application filed by Thomas Leung on or about April 13, 2001 entitled "Shear Wall Panel". All of the applications mentioned above are incorporated herein by this reference to them.

PCT. NO 6308469

what number

FIELD OF THE INVENTION

This invention relates to shear walls and, more particularly, to a prefabricated shear wall panel for use in frame construction.

BACKGROUND OF THE INVENTION

Shear walls or shear wall panels are used to resist lateral forces in a structure created, for example, by wind loads applied to the side of a structure or earthquakes. Conventional shear walls typically fall into three categories: (a) braced frames, (b) moment frames and (c) frames with structural sheathing.

In braced frames, a stud wall has braces which extend diagonally from the a rim joist or plate at the top of the wall to a rim joist, plate or foundation at the bottom of the wall. The braces cross one or more of the studs and therefore requires cuts in the studs to let the bracing into the wall or finish materials which can accommodate the protruding bracing member. In order to avoid cutting the studs significantly or to minimize how far the brace protrudes from the wall, the braces are typically made of a steel strip or rod or a thin wooden board. Since the bracing member is

longer than the wall studs, the slenderness of the bracing member limits its compressive strength and so the bracing members are installed in pairs slanting in opposite directions to provide a tensile member to resist lateral forces in either direction. In addition to these shortcomings, the braces typically occupy significant lengths of the walls which are then unavailable for windows.

In moment frames, various corners between studs and plates or joists are reinforced, typically with triangular steel plates or wooden knees. With the corners reinforced, lateral movement is resisted by moment in the studs which must bend before one of their ends can be displaced laterally while remaining vertical. This method may be suitable for timber frame or large I-beam structures in which the studs have large cross sections, but is inefficient when applied to light framing using "2 by" lumber or light metal channels. In these applications, the studs have limited moment resistance and large numbers of stud to plate or joist connections must be reinforced.

In frames with structural sheathing, plywood or oriented strand board are nailed to the studs and any sills, headers etc. used to frame openings. The sheathing panels are resistant to lateral deformation. When properly attached to the wall, the sheathing panels transfer this resistance to the wall primarily as a shear force around the perimeter of the sheathing panel. To resist this shear force, a concentrated nailing pattern is required around the perimeter of the sheathing panel. Any openings for windows require more intensive nailing and yet still weaken the panel such that some building codes deem sections of the wall with openings to have no lateral resistance. The process is time consuming and heavily dependant on quality workmanship. Further, in recent years it has been discovered that the tightly nailed sheathing panels in combination with an interior vapour barrier trap moisture within the wall which often leads to fungus growth and premature failure of the wall.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a shear wall panel. Various embodiments of the present invention are suitable for light framing, particularly in wood. Various embodiments of the present invention provide such a shear wall panel that does not require structural sheathing or interior vertical studs, that is suitable for pre-assembly in a factory, or presents reduced interference with placing windows in the structure.

The invention is directed at a shear wall panel for a building comprising,

a) a pair of spaced apart vertical members having upper ends and lower ends;

b) an upper horizontal member extending between and secured to the upper ends of the vertical members;

c) a lower horizontal member extending between and secured to the lower ends of the vertical members;

d) at least four diagonal members joined end to end in a multi-segmented assembly having at least three vertices between a first end and a second end,

wherein the multi-segmented assembly is located inside of the members in a), b) and c) above; one of the at least three vertices is secured to each of the members in a) and b) above; and, the first end and second ends are secured to the lower horizontal member.

The lower horizontal member is shear connected to a foundation or laterally stabilized wall or floor below the shear wall panel. The shear connection may include vertically oriented connectors connected to the lower ends of the vertical members to resist upward tensile forces on the vertical members. In an embodiment, these vertically oriented

connectors are wooden thrust blocks, preferably oriented so that the grain of the wood is vertical with a hole through the thrust blocks to accept a rod extending upwards from the foundation or a laterally stabilized wall or floor of the building below the shear wall panel. Alternatively or additionally, the shear wall panel may be connected to a foundation or laterally stabilized wall or floor of the building below the shear wall panel by tensile rods connected to a foundation or laterally stabilized wall or floor of the building below the shear wall panel. The tensile rods extend vertically through the shear wall panel near the vertical members and are secured to the shear wall panel near the top of the shear wall panel or near a solid structure adjacent the top of the shear wall panel.

Upper connectors transfer shear and tensile forces from a roof, floor or wall of the building above the upper horizontal member to the shear panel. In an embodiment, the upper shear connectors comprise metal straps, a first portion of which have teeth bent out of the metal strap, a second portion of which have holes for nailing through the metal strap into the roof, floor or wall of the building. Tensile metal straps have teeth whose width is parallel to a line dividing the first portion of the metal strap from the second portion of the metal strap. Shear metal straps have teeth whose width is perpendicular to a line dividing the first portion of the metal strap from the second portion of the metal strap

The invention is further directed at a shear wall panel as described above having wooden members attached to each other with toothed plates pounded through the members. The upper horizontal member preferably has a notch or extends beyond a vertical member so that the shear wall panel may be connected to the upper plates or upper horizontal members of adjacent wall panels.

The invention is further directed at a metal strap for connecting substantially abutting wooden members comprising, (a) a first

portion of the metal strap having teeth bent out of the metal strap; and, (b) a second portion of the metal strap having holes for nailing through the metal strap. An embodiment has teeth whose width is parallel to a line dividing the first portion of the metal strap from the second portion of the metal strap. Another embodiment has teeth whose width is perpendicular to a line dividing the first portion of the metal strap from the second portion of the metal strap.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described with reference to the following drawings:

Figure 1 is a perspective view of a shear wall panel according to an embodiment of the invention.

Figure 2 is a perspective view of a portion of the shear wall panel of Figure 1, the portion including a vertically oriented connecter according to an embodiment of the invention.

Figure 3 is a perspective view of a shear wall panel according to another embodiment of the invention.

Figure 4 is a perspective view of a shear wall panel according to another embodiment of the invention.

Figure 5 is a perspective view of another embodiment of the invention showing metal plate connectors.

Figure 6 is a perspective view of a shear connector

according to an embodiment of the invention.

Figure 7 is a perspective view of a tensile connector according to an embodiment of the invention.

Figure 8 is a perspective view of shear wall panels according to an embodiment of the invention in use in a first and second floor of a building.

Figure 9 is a perspective view of the shear wall panel of Figure 1 with alternative vertically oriented connectors.

Figure 10 is a perspective view of the shear wall panels of Figure 8 with alternative vertically oriented connectors.

Figure 11 is an elevation view of a shear wall panel according to another embodiment of the invention.

Figure 12 is a perspective view of a shear wall panel according to another embodiment of the invention.

Figure 13 is a perspective view of multiple shear wall panels according to an embodiment of the invention in use in a first floor of a building.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to Figure 1, a shear wall panel 10 for a building is shown. The shear wall panel 10 has a pair of spaced apart vertical members 12 having upper ends 14 and lower ends 16. An upper horizontal member 18 extends between and is secured to the upper ends 14 of the vertical members 12. A lower horizontal member 20 extends between

and is secured to the lower ends 16 of the vertical members 12. Four diagonal members 22 are joined end to end to create a multi-segmented assembly 24 inside of the rectangle formed by the vertical members 12, upper horizontal member 18 and lower horizontal member 20. The multi-segmented assembly 24 has three vertices 26, each attached to one of the vertical members 12 or the upper horizontal member 18, preferably at their midpoint. The multi-segmented assembly 24 also has first and second ends 27 attached to the lower horizontal member 20. In the embodiment shown in Figure 1, the first and second ends 27 are joined to each other so that the multi-segmented assembly 24 is a polygon. In such cases, the first and second ends 27 are preferably joined to the lower horizontal member 20 at its midpoint. The multi-segmented assembly, with the assistance of the vertical members 12, upper horizontal member 18 and lower horizontal member 20, preferably supports shear and vertical forces against the shear wall panel 10 substantially without the assistance of structural cladding or sheathing or continuous interior vertical studs. Studs may be added to support sheathing or other structures, and insulation and sheathing will be added to finish the wall, but these components are not relied on to assist in withstanding loads against the shear wall panel.

The shear wall panel 10 is adapted for use in a light timber frame. The vertical members 12, upper horizontal member 18, lower horizontal member 20 and diagonal members 22 (collectively referred to as members 28) are preferably made of wood. More preferably the members 28 are made of wood of the same width as studs in other parts of the light frame so that the shear wall panel 10 will be of the same width as the remainder of the wall. Further preferably, the members 28 are made of "2 by" nominal dimensional lumber which is usually more economical than using custom sized or larger dimension lumber. The "2 by" lumber may be doubled or tripled as required to withstand the design forces on the shear wall panel 10. For example, in shear wall panels 10 of up to 8 feet in width, the members 28 are typically made of doubled "2 by" lumber.

Although the members 28 may be nailed together, they are preferably connected with metal toothed plates 30 pressed or pounded through the members 28 wherever an end of one member 28 is adjacent another member 28. As in conventional stud framing, the upper horizontal member 18 and lower horizontal 20 extend to cover the overlap rather the vertical members 12. It is preferred if the members 28 directly abut each other, but the toothed plates 30 advantageously allow for small spaces between members 28 to be joined together such that moderately imprecise joinery can be tolerated. The shear wall panel 10 is manufactured by cutting and placing the members 28 on a table or work surface, positioned as described above, and then pounding or pressing the toothed plates 30 into the members 28 in the places described above and shown in the Figures. The configuration of the shear wall panel 10 allows all of the metal plates 30 to be pressed or pounded from outside the perimeter of the shear wall panel 10 avoiding the need to create sub-assemblies or alternate between cutting and placing operations and pressing or pounding operations .

Referring still to Figure 1, the shear wall panel 10 is shown attached to the foundation 32 of a building. The shear wall panel 10 may also be placed on top of a floor deck on top of the foundation 32 with suitable modifications to the description below. When a lateral force F, as produced by an earthquake or high wind such as a tornado or hurricane for example, is applied to the shear wall panel 10, it is resisted internally by compression stresses c and tensile stresses t and externally by reaction force R exerted by the foundation 32. Depending on the direction of lateral force F, either of the vertical members 12 can be placed in tension and tend to lift away from the foundation 32. To counteract this tendency, vertically oriented connections 34 adjacent the intersections between the lower horizontal member 20 and the lower ends 16 of the vertical members 12 connect the vertical members 12 to the foundation 32. Referring to Figures 1 or 2, the vertically oriented connection 34 is made of an anchor bolt 36 cast

in the foundation 32 which passes through the lower horizontal member 20 and a vertically oriented connector 38, both of which have holes or spaces to admit the anchor bolt 36. A washer 42 is placed over the anchor bolt 36 followed by a nut 40 which is threaded onto the anchor bolt 36 to complete the connection to the foundation 32.

The vertically oriented connector 38 may be a thrust block made of wood preferably oriented so that the grain of the wood is substantially vertical to take advantage of the increased compressive strength of the wood parallel to the grain. Such a vertically oriented connector 38 is attached by a metal plate 30 to the lower end 16 of the vertical member 12. Preferably, the metal plate 30 covers substantially all of the thrust block to confine the thrust blocks deformation and increase its compressive strength. Further preferably, the same metal plate 30 also attaches to the lower horizontal member 20 to provide a secure connection between the vertical member 12 and the lower horizontal member 20.

Vertically oriented connector 38 made of wood as shown in Figures 1 and 2 are easily and inexpensively included in the shear wall panel 10 during manufacture. The thrust blocks shown in Figures 1 and 2 in particular are made of two blocks of "2 by" material with a space between them to accept the anchor bolts 36 thus avoiding the need to drill a hole through the thrust blocks while allowing the anchor bolt 36 to be near the vertical members 12 for low eccentricity. In narrow shear wall panels 10 (typically less than eight feet wide) under some loads, however, a wooden vertically oriented connector 38 may need to be larger than shown and have a plurality of holes for a plurality of anchor bolts 36 to provide sufficient strength. In these cases, suitable commercially available vertically oriented connectors 38 are preferred.

Additional foundation connections 44 are made of anchor bolts 36 cast in the foundation 32 which pass through the lower horizontal

member 20 and are held in place by a nut 40 and washer 42. Where the shear wall panel 10 is attached to a floor attached to the foundation 32, the vertically oriented connections 34 and foundation connections 44 pass through the floor. In combination, the foundation connections 44, and vertically oriented connections 34 shear connect the shear wall panel 10, meaning that they transmit the reaction force R to the shear wall panel 10 and resist the tensile forces on the members 28 connected to the lower horizontal member 20. For the purposes of calculations, however, it is assumed that the vertically oriented connections 34 resist all of the tensile forces on the vertical members 12. Where the multi-segmented assembly 24 is a polygon, tensile forces on one diagonal member 22 are counteracted by adjoining diagonal members 22. In these cases, special vertically oriented connections 34 are typically not required where the diagonal members 22 attach to the lower horizontal member 20.

Depending on the exterior and interior wall coverings or fixtures, nailers 46 may be nailed into the shear wall panel 10 as required. Similarly, if a window is required in the shear wall panel 10, headers 48 and sills 50 can be nailed inside the shear wall panel 10. If these requirements are known early enough, the nailers 46, upper sills 48 and lower sills 50 can also be attached with metal plates when the shear wall panel 10 is assembled. In shear wall panels 10 of sufficient width, the open space in the centre of the shear wall panel 10 provides considerable architectural freedom for placing windows within a shear wall.

Despite the large opening in its centre, the shear wall panel 10 is surprisingly effective in supporting vertical loads on the wall. Vertical load is first supported by the upper horizontal member 18 and transferred to the vertical members 12 and to the vertex 26 of multi-segmented assembly 24 abutting the upper horizontal member 18. The upper diagonal members 22 further transmit vertical load to the lower portions of the vertical members 12. The lower diagonal members 22 counteract the lateral

component of the force transferred by the upper diagonal members 22 so that the vertical members 12 are not bent laterally. Because the multi-segmented assembly 24 can support a vertical load, a large opening is provided without the need to design the upper horizontal member 18 as a conventional header.

Referring now to Figures 3, 4 and 12, alternate embodiments of the shear wall panel 10 are shown which provide even greater space for a window opening and, in the case of Figure 4, for a door opening. In these Figures, the multi-segmented assembly 24 is formed of additional diagonal members 22 creating additional vertices 26. These additional vertices 26 are connected by extenders 52 to corners formed by the intersection of the vertical members 12 with either the upper horizontal member 18 or the lower horizontal member 20. In other respects, the shear wall panels in Figures 3, 4 and 12 are similar to the shear wall panel 10 in Figure 1 although the distribution of internal forces differs slightly. In Figure 4, an additional difference is that the first and second ends 27 of the multi-segmented assembly 24 are not joined to each other to make a polygon. In this case, shear forces on the shear wall panel 10 creates an upwards force at one of the first or second ends 27 that is not resisted by the other. To counter the upwards force, foundation connections 44 are placed adjacent the first and second ends 27. Depending on the load, however, additional vertically oriented connections 34 may be required in place of the foundation connections 44. To install a very large window, a shear wall panel can be used which repeats the structure of the upper half of Figure 3 as the lower half of the shear wall panel as shown in Figure 12. In this case, the two lowest diagonal members 22 of Figure 3 are each replaced by two diagonal members 22 connected by extenders 52 at the newly created vertices to corners between the vertical members 12 and the lower horizontal member 20.

Referring now to Figure 5, a shear wall panel 10 is shown

attached to a superior structure 54 above it. The superior structure 54 could be, for example, a roof, a header over a large opening such as a garage door or the wall or floor of a second story. In a high wind, such as a tornado or hurricane, or during an earthquake, for example, the superior structure 54 may be subject to a lateral force applied above the upper horizontal member 18. Accordingly, moment and shear forces will be created between the superior structure 54 and the upper horizontal member 18 of the shear wall panel 10. In other cases, such as where the superior structure 54 is a header over a large opening, similar moment and shear forces are created when a lateral force is applied anywhere to the structure. These forces are resisted by attaching the superior structure 54 and the upper horizontal member 18 together, preferably with strap connectors 56.

Referring to Figures 5, 6 and 7, the strap connectors 56 are made of metal straps having a first portion 58 with teeth 60 bent out of the metal strap and a second portion 62 with holes 64 for nailing through the metal strap into the roof, floor or wall of the building. In Figure 7, a tensile metal strap 66 is shown, having teeth 60 whose width is parallel to a line dividing the first portion 58 of the strap connector 56 from the second portion 62 of the strap connector 56. As shown in Figure 5, the first portion 58 of the tensile metal strap 66 is attached to the upper ends 14 of the vertical members 12 and the second portion 62 of the tensile metal strap 66 extends upwards from the shear wall panel 10 to be nailed to the superior structure 54. In Figure 6, a shear metal strap 68 is shown having teeth 60 whose width is perpendicular to a line dividing the first portion 58 of the strap connector 56 from the second portion 62 of the strap connector 56. The first portion 58 of the shear metal strap 68 is attached to the upper horizontal member 18 and the second portion 62 of the shear metal strap 68 extends upwards from the shear wall panel 10 to be nailed to the superior structure 54.

Now referring to Figure 8, a shear wall panel 10 on a first

floor is attached to a second floor 70 of a superior structure 54. An upper floor shear wall panel 110 is located above the shear wall panel 10 below, preferably such that their vertical members 12 are directly one above the other. The tensile metal straps 66 are not used, but rather second floor vertically oriented connectors 134 are used. The second floor vertically oriented connectors 134 are analogous to the vertically oriented connections 34 except that the foundation bolt 36 is replaced by a through bolt 136 threaded on both ends to receive nuts 40 and upper thrust blocks 138 are provided in the upper corners of the shear wall panel 10. The lower horizontal member 20 of the upper floor shear wall panel 110 is shear connected to the laterally stabilized floor wall or floor below by the second floor vertically oriented connectors 134 and by shear metal straps 68. The first portion 58 of the shear metal straps 68 is attached to the lower horizontal member 20 and their second portion 62 extends downwards from the upper floor shear wall panel 110 to be nailed to the second floor 70 or the shear wall panel 10 below. In this way, shear wall panels 10 can be provided for multistorey buildings efficiently at least up to 4 stories high. Where the foundation 32 is wood or separated from the shear wall panel 10 by a wooden floor deck, shear metal straps 68 (shown in dashed lines) may be used with or in place of foundation connections 44.

To connect the shear wall panel 10 to an adjoining wall panel, the upper-most board of the upper horizontal member 18 may be extended beyond the vertical members 12. This extended board laps over the top plate of an adjacent wall panel forming part of a conventional double top plate. Alternatively, as shown in Figure 8, the entire upper horizontal member 18 may be extended beyond the vertical members 12 in which case the studs of an adjacent wall panel are attached directly to the extended upper horizontal member 18. Further alternatively, as shown in Figure 13, the shear wall panel 10A can also be integrated with one or more other wall panels 610 (which may or may not be a shear wall panel 10B) by placing one or more plates 600 over the upper horizontal member 18 of the

shear wall panel 10 and extending the one or more plates 600 to the other panels 610. This involves more material than the methods above but avoids the need for extended upper horizontal members 18 which may be an advantage if the shear wall panels 10 are assembled off site.

Referring now to Figures 5, 9 and 10, a tensile rod connection 100 is shown (in dashed lines in Figure 5) between a shear wall panel 10, 110 and a foundation 32 (Figures 1 and 5) or laterally stabilized wall 10 or floor 70 (Figure 8) of a building below the shear wall panel. This alternative connection may be used in addition to or in place of the previously described vertically oriented connections 34, 134. As for the vertically oriented connections 34, 134, foundation connections 44 and shear metal straps 68 may be used in addition to the tensile rod connection 100 but are generally assumed not to resist any tensile forces on the vertical members 12.

The tensile rod connection 100 comprises a tensile rod 102, typically made of steel and threaded at least at its ends. The tensile rods 102 extend vertically through the shear wall panel 10, 110 near the vertical members 12. The tensile rods 102 are secured near the top of the shear wall panel 10, 110 or near a solid structure adjacent the top of the shear wall panel 10, 110 such as a superior structure 54 (Figure 5), floor 70 or upper floor shear wall panel 110 (Figure 8). The tensile rods 102 are secured to the foundation 32 (Figures 1 and 5) or a laterally stabilized wall 10 or floor 70 (Figure 8) of a building below the shear wall panel, preferably by threaded couplers 104 connected to anchor bolts 36 in a foundation 32 or to a threaded rod 102 from a lower floor of the building which is in turn connected to the foundation 32. The tensile rods 102 are preferably secured to the shear wall panel 10, 110 by nuts 106 screwed down over washers 108 to put the tensile rods 102 slightly in tension. The nuts 106 preferably abut (a) the top of the upper horizontal member 18 of a shear wall panel 10 (as in Figure 1) where no significant shear or moment forces are expected between a superior

structure 54 and the upper horizontal member 18, (b) the top of the superior structure 54 (as in Figure 5) where significant shear or moment forces are expected between a superior structure 54 and the upper horizontal member 18 and (c) the top of the lower horizontal member 20 of an upper floor shear wall panel 110 (as in Figure 8) when there is one. Vertically oriented connectors 38 are described earlier are preferably used below each nut 106 or below upper horizontal members 18 where a nut will be used above the upper horizontal members.

Referring now to Figure 11, another shear wall panel 510 is shown. The shear wall panel 510 is similar to the preceding panels, and may similarly be used in assemblies of pluralities of panels as described above. The members 28 are made of doubled "2 by" nominal dimensional lumber, the width depending on the anticipated loading, although other materials might also be used. The members 28 are preferably connected with metal toothed plates 30 pressed or pounded into the members 28 wherever an end of one member 28 is adjacent another member 28. The shear wall panel 510 is manufactured as has been described above.

The shear wall panel 510 is shown attached to the foundation 32 of a building or a laterally stabilized floor or wall below. The shear wall panel 510 may also be placed on top of a floor deck on top of the foundation 32 with suitable modifications to the description below. The shear wall panel 510 is connected to the foundation 32 so as to resist a lateral force applied to the shear wall panel 510 with vertically oriented connections 34 which connect the vertical members 12 to the foundation 32. The vertically oriented connection 34 is made of an anchor bolt 36 cast in the foundation 32 which passes through the lower horizontal member 20 and is connected to a tensile rod connection 100. The tensile rod connection is as described in Figure 9 except that the tensile rod 102 extends vertically through the shear wall panel 510 only to vertically oriented connectors 38 adjacent the vertexes 26 adjacent the vertical members 12 as shown in

Figure 11. To attach a second story or roof deck above the shear wall panel 510 of Figure 11, more connectors 104 would be attached above the vertically oriented connector 538 so that more tensile rods 102 can extend upwards to the roof deck or to the vertically oriented connectors of an upper floor shear wall panel 10, 110, 510. The tensile rods 102 are preferably secured to the shear wall panel 510 by nuts 106 screwed down over washers 108 to put the tensile rods 102 slightly in tension. The washers 108 abut a vertically oriented connector 538 adjacent the intersections between the vertical members 12 and the diagonals 22. The inventor has observed that this location for the vertically oriented connector 538 provides a good degree of ductile elongation of the bolt 36 in earthquake loads and avoids stress cause by the eccentricity of the bolt 36 on the horizontal members 18, 20.

The vertically oriented connector 538 may be a wedge-shaped thrust block made of wood preferably oriented so that the grain of the wood is substantially vertical to take advantage of the increased compressive strength of the wood parallel to the grain. The vertically oriented connector 538 is attached by a metal plate 30 which preferably covers substantially all of the thrust block. The vertically oriented connector 38 may be made of two blocks of "2 by" material as described above or by drilling a hole in a solid block of wood. Commercial available (typically metal) vertically oriented connectors 538 might also be used at the same location. Additional foundation connections 44 may be used as described above if required, although they typically are not in a 4 foot wide panel as shown in Figure 11.

The shear wall panel 510 may be attached to a superior structure 54 above it as described in Figure 5, for example, with strap connectors as described in Figures 5-7. The shear wall panel 510 may also be attached to a shear wall panel 510 on a second floor in a manner analogous to that shown in Figure 8 but with the vertically oriented connectors 38 attached to structure below each shear wall panel 510 being located as shown

in Figure 11. The shear wall panel 510 may be connected to adjoining wall panels 510 as described for other panels above. The vertically oriented connector 34 shown in Figure 11 may be used in other embodiments of the shear wall panel, for example the embodiments of Figures 3, 4, 5 and 12, as shown, for example, in Figure 12.

It is to be understood that what has been described are preferred embodiments of the invention. The invention, however, may be altered and applied to alternative embodiments within the spirit of the invention as described above, and the scope of the claims set out below. In particular, the embodiments described above are suitable for use in light timber framing. It will be apparent to those skilled in the art, however, that the some aspects of the invention may be applied to other structural systems, particularly light gauge metal, engineered steel and timber framing.